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PHYTOPLANKTON, CHLOROPHYLL *a*, AND PRIMARY PRODUCTION IN LAKE OKEECHOBEE

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by

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SOUTH FLORIDA WATER MANAGEMENT DISTRICT
Department of Resource Planning
Water Chemistry Division

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SUMMARY

Limnetic chlorophyll *a* data collected from 1979 to 1982 were compared to data collected from 1974 to 1976. Mean annual chlorophyll concentrations in 1980 and 1981 were slightly less than mean values measured in 1975 and 1976. However, the two highest chlorophyll peaks (116.8 and 119.3 mg/m^3) observed in Lake Okeechobee were measured in 1981 when the lake level was very low. The average concentration for the 1974-82 period was 23.2 mg/m^3. Chlorophyll concentrations of other Florida lakes range from 0.9 to 276.6 mg/m^3 (Baker, et al. 1981). A value above 10 mg/m^3 indicates a eutrophic condition (Federico, et al. 1981). Mean chlorophyll levels on the north and west sides of the lake were significantly higher than on the south side.

Several regression equations designed to predict chlorophyll levels from concentrations of phosphorus and nitrogen were tested and the equation of Smith (1982) gave the best estimate of the measured mean chlorophyll value. These simple models are useful only in predicting large-scale changes in lake chlorophyll concentrations.

Phytoplankton productivity rates were also examined for the period 1973-82. Gross productivity averaged 1245 mg C/m^3-day in 1973-76. The mean gross productivity in 1981-82 was higher (1852 mg C/m^3-day) due to a high measurement during a bloom in the lake's north end in July 1981. The 1973-82 mean productivity rate of 107 mg C/m^3-hour compares to measurements of 0.33 to 1020 mg C/m^3-hour) for other Florida lakes (Brezonik, et al. 1969). As with chlorophyll, productivity was greater in the north than in the south. Table 1 summarizes the mean lake chlorophyll and productivity values during the period of study.

TABLE 1. SUMMARY OF LAKE OKEECHOBEE CHLOROPHYLL A AND GROSS PRIMARY PRODUCTIVITY ANNUAL MEAN VALUES

Year	Chlorophyll a [1/] (mg/m^3)	Gross Primary Productivity ($mg\ C/m^3$-day)
1973	-	1188 [2/]
1974	-	1349 [2/]
1975	26.9	1358 [2]
1976	25.8	1084 [2/]
1980	17.6	-
1981	19.5	1852 [3/]

1/ Mean of stations 1 to 8

2/ Mean of stations 1, 4, 5, and 6

3/ Mean of stations 2 and 6; period from May 1981 to May 1982

The dominant algal species identified in 1981 were similar to those documented in 1974. Blue-green algae were found in the largest numbers and formed the most significant blooms. Bloom species in 1981 included Rhaphidiopsis curvata and Anacystis sp.

The conclusion of this report is that chlorophyll and productivity levels have not changed substantially during the period of study, except that peak values measured in 1981 were higher than previously observed. It is not known why chlorophyll concentrations and productivity rates are greater in the lake's north end, but the possibility that algal production is more heavily influenced by nutrient inflows from the north, particularly phosphorus inputs from Taylor Creek/Nubbin Slough, should be investigated. Since average chlorophyll and productivity values are lowest in the south end of the lake, it appears that runoff backpumped from the Everglades Agricultural Area has not appreciably affected limnetic algal production over the long term, but significant impacts under certain conditions are possible. A large bloom in the south end was observed to follow intensive backpumping in the summer of 1981. Currently, the relationship of phytoplankton composition and density to water quality variables is being investigated.

INTRODUCTION

As one of south Florida's most important resources, Lake Okeechobee has received much concern regarding the possible degradation of its water quality. The South Florida Water Management District has gathered a large amount of water quality and biological data dating back to 1973. Davis and Marshall (1975) and Marshall (1977) presented earlier data relating to phytoplankton. This report summarizes information collected up to 1982, including chlorophyll, productivity, and phytoplankton density and taxonomic data. Seasonal and spacial trends are discussed and recent data is compared with those of earlier years. In addition, some recently published chlorophyll models are evaluated for use in predicting average chlorophyll concentrations from lake phosphorus and nitrogen values.

MATERIALS AND METHODS

This report covers chlorophyll data collected from September 1974 to March 1982, primary productivity data collected from January 1973 to May 1982, and phytoplankton sampled in 1981. All years referred to in this report are calendar years.

Chlorophyll

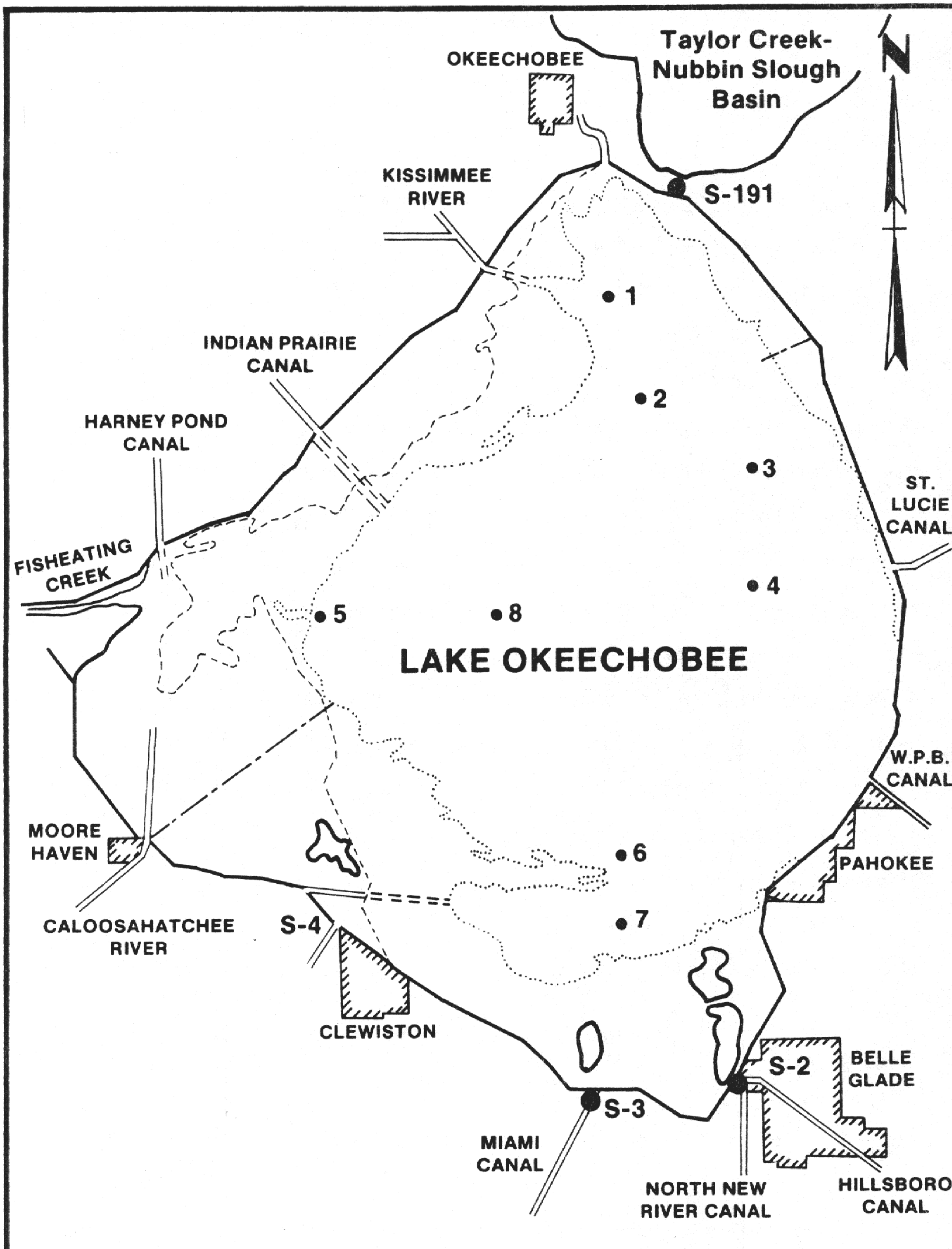
Chlorophyll *a* was measured at eight lake stations (Fig. 1) every 18 days from September 1974 to December 1976, and monthly from December 1979 to the present. Samples were taken within 0.5 meters of the water surface. Various other chemical and physical parameters were also measured either *in situ* or in the laboratory. Methods of analysis for chlorophyll and these other parameters have been described by Federico, et al. (1981). Chlorophyll *a* data have not been corrected for phaeophytin.

Primary Productivity

Primary production was determined by the light and dark bottle method (Strickland and Parsons 1968). This method measured algal production (or respiration) by the gain (or loss) of dissolved oxygen in clear and opaque glass bottles incubated *in situ* at various depths. The technique is explained further by Marshall (1977). Bottles were incubated at depths from 0 to 2 meters, but this report only includes data from a depth of 0.22 meters. Marshall found that 0.22 m is about the depth at which maximum productivity occurs. Productivity was measured at stations 1, 4, 5, and 6 during the years 1973-77 and at 2 and 6 during 1981-82. The frequency of measurement was usually monthly or bi-monthly.

Phytoplankton

Phytoplankton sampled in 1981 were composited from depths of 0.5 and 2.0 meters. Counting and identification methods are found in Marshall (1977).



EVERGLADES AGRICULTURAL AREA

Fig. 1 Lake Okeechobee Water Quality Monitoring Stations

RESULTS

Chlorophyll

Chlorophyll Data from Eight-Station Monitoring Network

Chlorophyll *a* has been widely used as an indicator of lake trophic state. According to sources listed by Federico, et al. (1981), chlorophyll values above 6.0 to 10.0 mg/m^3 indicate a eutrophic condition. Federico, et al. calculated an average Lake Okeechobee chlorophyll concentration (1974-76) of 25.7 mg/m^3 which suggested that the lake was eutrophic. This agreed with their assessment derived from other trophic state indicators and indices.

Data collected from December 1979 to March 1982 show that there have been no recent increases in mean chlorophyll levels. Instead, the 1980 and 1981 average values are significantly less than those of 1975 and 1976 (Table 2). Therefore, the chlorophyll data do not suggest any general increase in algal biomass over the period of study. The average concentration for the 1974-82 period is 23.2 mg/m^3. In comparison Baker, et al. (1981) listed mean chlorophyll concentrations ranging from 0.9 to 276.6 mg/m^3 for 101 Florida lakes. A value above 10 mg/m^3 is considered to indicate a eutrophic condition (Federico, et al. 1981).

TABLE 2. DUNCAN'S MULTIPLE RANGE TEST FOR CHLOROPHYLL MEANS BY YEAR [1/]

Year	1980	1981	1976	1975
Conc. (mg/m^3)	17.6	19.5	25.8	26.9
	A	A		
			B	B

1/ Means with same letter are not significantly different (α= .05).

Although mean chlorophyll values are commonly used in evaluating a lake's trophic state, chlorophyll maximums are probably more important in describing the impacts of eutrophication on the lake ecosystem. As a lake becomes more eutrophic, seasonal chlorophyll peaks become higher as algal blooms increase in magnitude. The two highest chlorophyll peaks in Lake Okeechobee were observed in 1981. At Station 7, in the lake's south end, a concentration of 119.3 mg/m^3 was measured during a fall bloom of Anacystis. A bloom of Rhaphidiopsis curvata in July was responsible for a value of 116.8 mg/m^3 at Station 2 on the north side of the lake.

Figures 2 to 5 show that there are seasonal variations in chlorophyll values, although no highly regular patterns exist. The highest concentrations occur in the summer and fall months while the lowest values are usually found in the winter. A spring chlorophyll peak may also be present. A comparison of monthly averages shows that chlorophyll generally increases from winter to fall with the peak month being November (Table 3). With respect to seasonal variations, Lake Okeechobee appears to follow a pattern somewhat between that of a temperate and a tropical lake. In a typical lake at more northern latitudes, algal biomass reaches maximums in the spring and late summer/autumn, sometimes increasing as much as a thousandfold. Tropical lakes usually have much less seasonal variation, and maximums are often observed in the winter (Wetzel 1975).

Some differences between stations can be noted in Figures 2 to 5. First, Stations 1 and 2 are more subject to high chlorophyll peaks than Stations 3 and 4 which are less influenced by nutrient-rich inflows from the north. Also, Station 5 has a somewhat different seasonal pattern from the northern stations. Peak concentrations at this station occur in the fall and spring, while the lowest concentrations are often found in the summer. The south end of the lake, represented by Stations 6 and 7, has the lowest mean concentrations but is also subject to algal blooms as mentioned above. In general, mean chlorophyll levels decrease from north to south (Table 4).

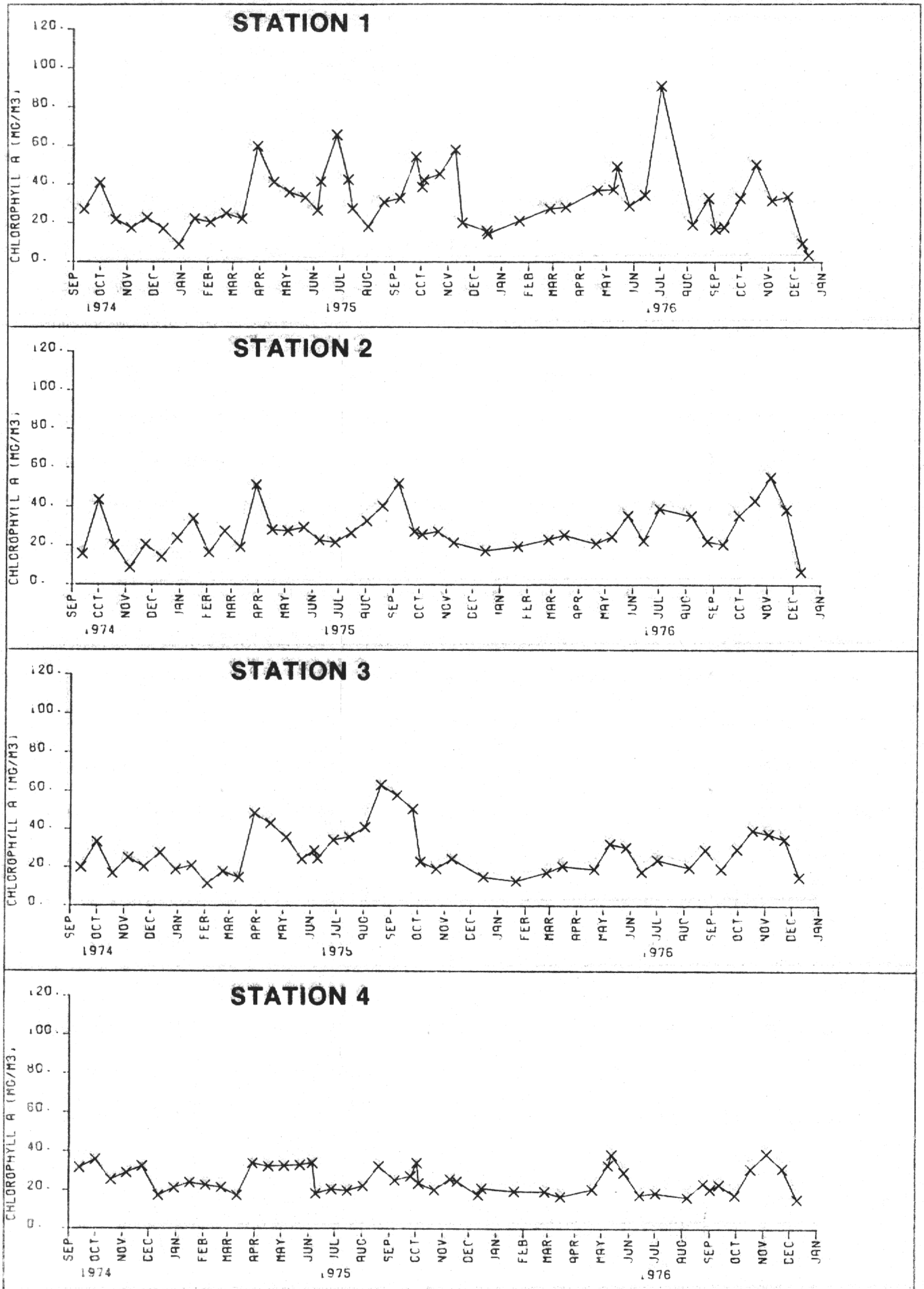


Fig. 2 Chlorophyll 1974-76

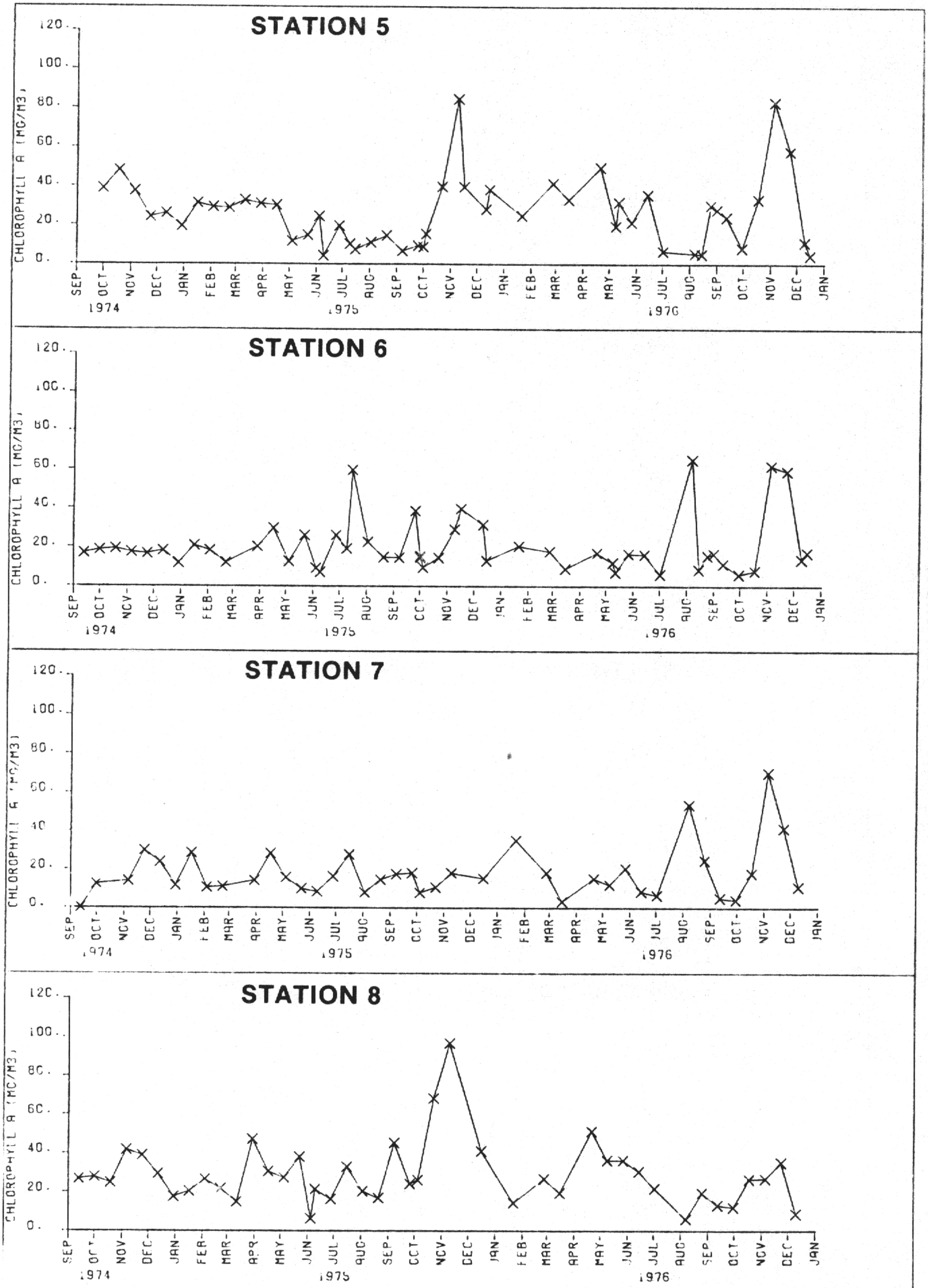


Fig. 3 Chlorophyll 1974-76

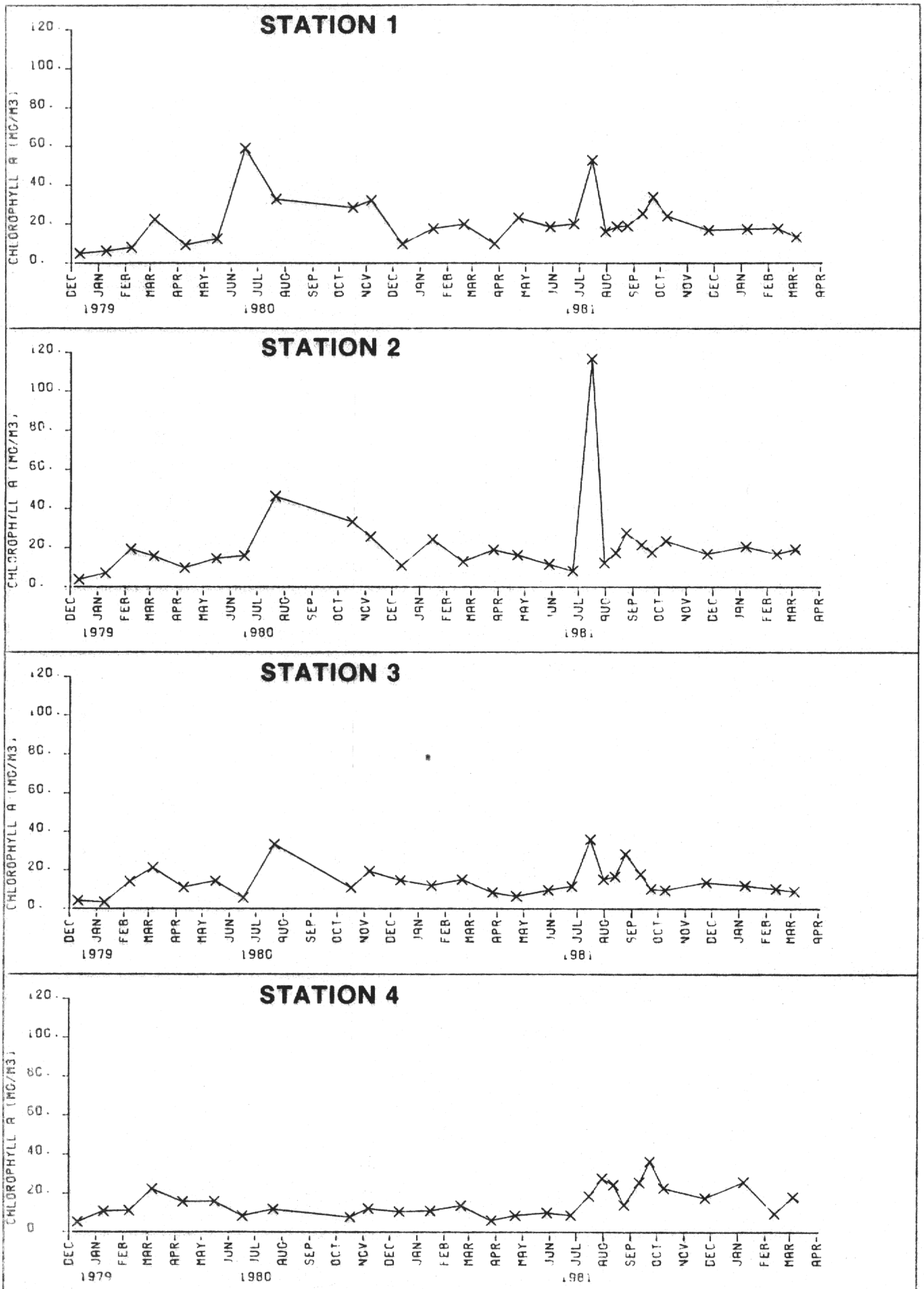


Fig. 4 Chlorophyll 1979-82

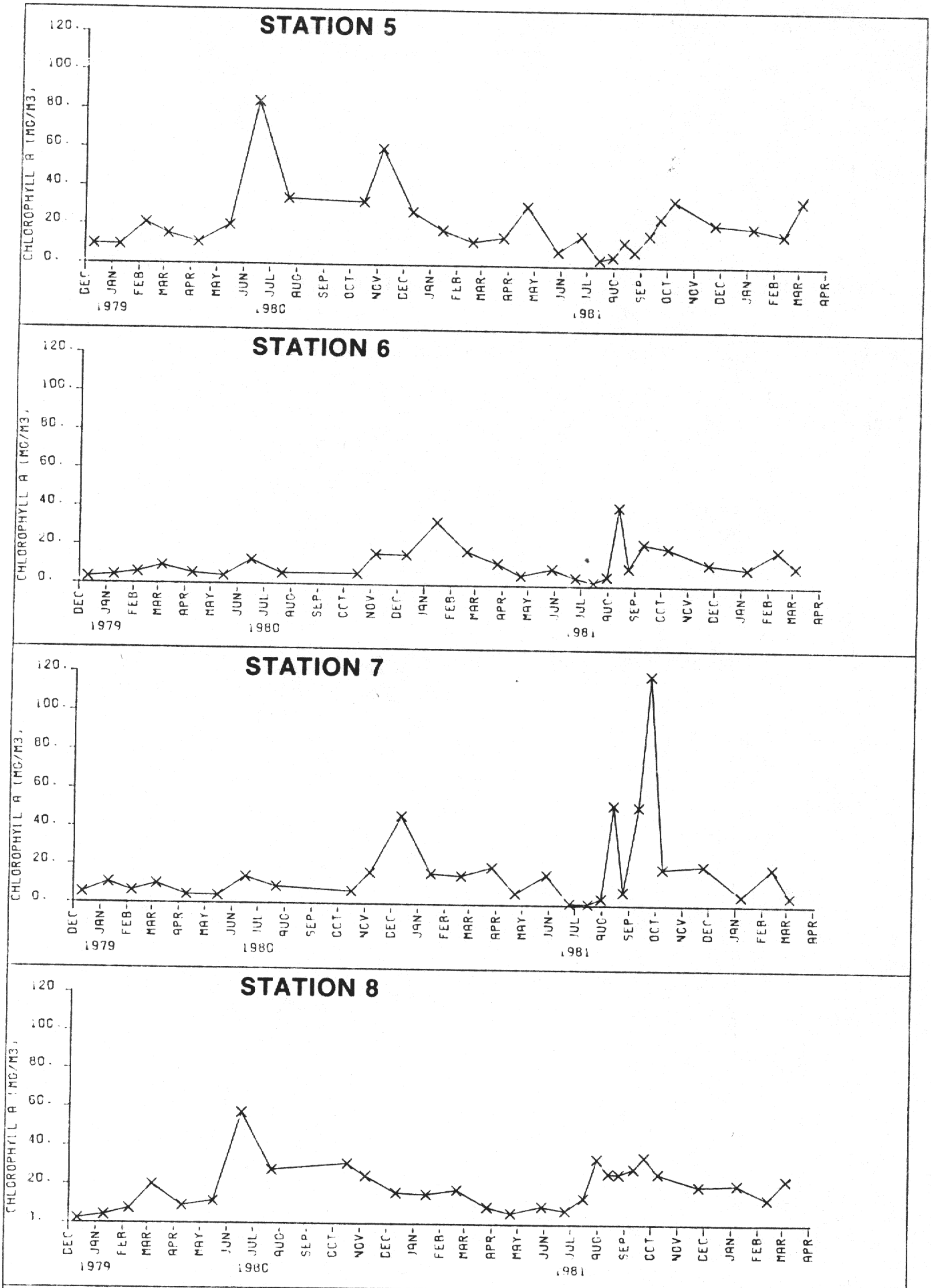


Fig. 5 Chlorophyll 1979-82

TABLE 3. DUNCAN'S MULTIPLE RANGE TEST FOR CHLOROPHYLL MEANS BY MONTH 1/

Month	Feb.	Dec.	Jan.	Mar.	Apr.	June	May	Aug.	July	Oct.	Sep.	Nov.
Conc. (mg/m^3)	17.4	17.8	19.7	20.7	21.0	22.1	22.1	23.7	25.3	25.7	25.8	32.7
	A	A	A	A	A	A	A	A				
			B	B	B	B	B	B	B	B	B	
												C

TABLE 4. DUNCAN'S MULTIPLE RANGE TEST FOR CHLOROPHYLL MEANS BY STATION 1/

Station	6	7	4	3	5	8	2	1
Conc. (mg/m^3)	17.9	18.3	21.5	22.6	25.2	25.6	25.6	28.4
	A	A	A	A				
			B	B	B	B	B	
					C	C	C	C

1/ Means with same letter are not significantly different (α= .05).

Station means range from 28.4 mg/m^3 at Station 1 to 17.9 mg/m^3 at Station 6. Northern and western station means are significantly higher than southern station averages.

Chlorophyll-Nutrient Relationships

It has been shown that chlorophyll a is highly correlated with total phosphorus (TP) concentrations in a broad range of temperate lakes (Sakamoto 1966; Dillon and Rigler 1974; Jones and Bachmann 1976; Carlson 1977). Baker et al. (1981) and Canfield (1983), working with Florida lake data, also found a high correlation between chlorophyll and total nitrogen that was stronger than the chlorophyll-phosphorus relationship. This would be expected since a larger percentage of Florida lakes are nitrogen-limited. These relationships have been the basis for regression equations designed to predict chlorophyll from lake nutrient values. These chlorophyll models may be used in conjunction with nutrient input-output models to predict gross changes in chlorophyll with increased or reduced nutrient loading. Since nitrogen is more often the limiting nutrient in Florida lakes, models incorporating total nitrogen are generally better at estimating chlorophyll than equations that include only total phosphorus. These published models (Table 5) were tested with Lake Okeechobee data.

The models of Baker, et al. (1981) were developed from 100 Florida lakes. In addition to the two models given here, Baker, et al. presented several other models, including equations that relate chlorophyll concentrations to nutrient loading rates. These other models, however, were based on more restricted data sets or had lower r^2 values and are not evaluated here. Like the models that follow, Baker, et al. used mean annual concentrations since Florida lakes are usually mixed continuously and have a year-round growing season. Researchers (Dillon and Rigler 1974; Jones and Bachmann 1976) working

TABLE 5. APPLICATION OF CHLOROPHYLL MODELS TO LAKE OKEECHOBEE

	1975	1976	1980	1981	Avg. Conc.	Avg. Error[2]
Measured values:						
Number of observations [1]	161	101	80	111	-	-
Mean TP (mg/L)	0.049	0.050	0.096	0.074	0.067	-
Mean TN (mg/L)	1.42	1.70	2.36	2.59	2.02	-
Mean chlorophyll a (mg/m^3)	27.1	24.6	17.9	19.4	22.3	-
Estimated chlorophyll values:						
Baker et al. (1981) [3]						
log (chl a) = 0.79 log (TP) - 0.41 $r^2 = 0.72$	8.4	8.6	14.3	11.7	10.8	11.5
log (chl a) = 1.46 log (TN) + 1.03 $r^2 = 0.77$	17.9	23.3	37.5	43.0	29.9	13.4
Smith (1982) [4]						
log (chl a) = 0.374 log (TP) + 0.935 log (TN) - 2.488 $r^2 = 0.83$	12.3	14.7	25.5	25.3	19.3	9.6
Canfield (1983) [4] log (chl a) = 0.269 log (TP) + 1.06 log (TN) - 2.49 $r^2 = 0.81$	20.2	24.6	41.5	42.7	32.0	13.5
log (chl a) = 0.744 log (TP) - 0.15 $r^2 = 0.59$	12.8	13.0	21.1	17.4	16.2	7.8
log (chl a) = 1.38 log (TN) - 2.99 $r^2 = 0.77$	22.9	29.4	46.2	52.5	37.3	17.6

1/ Only observations having values for each parameter were included in the data set.

2/ Average error is the mean of the absolute values of the differences between the calculated and measured values.

3/ TP and Chl a in mg/m^3, TN in mg/L

4/ All units in mg/m^3

on more northerly lakes have used spring TP and summer chlorophyll in their models, but Baker et al. found no justification for restricting their data in this manner.

In an effort to improve upon existing models, Smith (1982) concluded that variations in the TN:TP ratio account for a substantial portion of the scatter observed in linear regression equations relating chlorophyll to total phosphorus. When Smith divided lakes into groups based on their TN:TP ratios, he found that a reduction of chlorophyll yield per unit TP accompanied a drop in the TN:TP ratio. In other words, the slope of the chlorophyll-TP regression is lower for those lakes with low TN:TP ratios (eutrophic, nitrogen-limited lakes). Smith suggested that the effects of TN:TP ratio on algal biomass appear to be driven by species shifts in the phytoplankton. As the TN:TP ratio decreases as a result of greater phosphorus loading, the dominant species shift from green algae and diatoms to blue-green algae. To account for the effect of the TN:TP ratio on chlorophyll yield, Smith included both TN and TP in a multiple regression model that yielded better results than the linear regression equation with TP alone. Using the data set of Baker et al., he formulated a similar model for Florida lakes.

Canfield (1983) reached the same conclusion regarding the TN:TP ratio and presented a similar chlorophyll model. This multiple regression model also produced better results than models using TP or TN alone. Canfield's models were developed from data on 223 Florida lakes, including the data of Baker et al.

Among the equations given in Table 5, Smith's model came closest to estimating the average chlorophyll concentration over four years. This model was also more precise than most of the others, having the second lowest average error (the mean of the absolute differences between calculated and measured values). Canfield's linear regression model using TP was the most precise, but underestimated the average concentration by a greater amount.

Although the models provide fair to good approximations of Lake Okeechobee chlorophyll concentrations, they are incapable of predicting year to year variations. As shown in Table 5, TP and TN were greater in 1980 and 1981 than in 1975 and 1976, but chlorophyll was lower than in the earlier years; however, the models predict greater chlorophyll concentrations in 1980 and 1981. Thus, these models are valuable only in predicting long-term trends; even then, these simple equations only allow first approximations of large scale changes.

For example, Canfield has included 95% confidence limits of 29 to 319% for use with the predicted chlorophyll value given by his multiple regression model. Thus, for the model's predicted average chlorophyll value of 32.0 mg/m^3, the actual concentration could be expected to fall between 9.3 and 102.1 mg/m^3 (which it does).

To predict what might happen if nutrient loading rates were reduced, this chlorophyll model can be coupled with the modified Vollenweider (1976) input-output model used by Federico, et al. (1981). If phosphorus and nitrogen loadings were reduced to their excessive loading rates (the rates at which the lake has an equal chance of being either eutrophic or mesotrophic), the modified Vollenweider (1976) model predicts that average in-lake TP and TN concentrations would be 0.040 and 0.90 mg/L, respectively (Table 6). Using these TP and TN values in Canfield's model gives a predicted chlorophyll value of 11.8 mg/m^3 with a confidence interval of 3.4 to 37.6 mg/m^3. Therefore, a 55% chance of observing reduced chlorophyll concentrations could be expected by the ratio:

TABLE 6. ANALYSIS OF THE EFFECT OF REDUCED NUTRIENT LOADINGS ON LAKE OKEECHOBEE CHLOROPHYLL

Modified Vollenweider (1976) phosphorus model:

$$TP = 0.682\ (L_c(P)exc./(q_s\ (1 + \sqrt{\tau_\omega})\ )\ )^{0.934} = 0.040 \text{ mg/L}$$

where,

$L_c(P)exc.$ = excessive phosphorus loading rate (0.209 g P/m^2-yr)

q_s = hydraulic loading rate (1.52 m/yr)

τ_ω = water residence time (3.47 years)

Modified Vollenweider (1976) nitrogen model:

$$TN = 1.29\ (L_c(N)exc./(q_s\ (1 + \sqrt{\tau_\omega})\ )\ )^{0.858} = 0.90 \text{ mg/L}$$

where,

$L_c(N)exc.$ = excessive nitrogen loading rate (2.87 g N/m^2-yr)

q_s and τ_ω are as above

Canfield (1983) chlorophyll model:

$$\log(\text{chl a}) = 0.269 \log(40 \text{ mg/m}^3) + 1.06 \log(900 \text{ mg/m}^3) - 2.49$$

chl a = 11.8 mg/m^3 with confidence limits of 3.4 and 37.6 mg/m^3

Smith (1982) chlorophyll model:

$$\log(\text{chl a}) = 0.374 \log(40 \text{ mg/m}^3) + 0.935 \log(900 \text{ mg/m}^3) - 2.488$$

chl a = 7.5 mg/m^3, no confidence limits available

Chance of reduction =

$$\frac{22.3\ mg/m^3\ (1975\text{-}81\ avg.\ conc.) - 3.4\ mg/m^3}{(37.6 - 3.4)\ mg/m^3}$$

This analysis, however, falsely assumes that (1) there is zero error in the nutrient input-output model, (2) internal nutrient loadings are not important, and (3) TP and/or TN are the only limiting growth factors. Thus, the value of the present chlorophyll models for predicting future chlorophyll concentrations in Lake Okeechobee is questionable. A more in-depth evaluation of chlorophyll modeling needs to be done (see also the analysis by Brezonik, et al. 1979). These models might be used successfully on other lakes within the District, for example, Lake Tohopekaliga.

Primary Productivity

Table 7 summarizes the results for gross primary productivity. Gross productivity is the total rate of organic matter synthesized by the phytoplankton. Net productivity is the rate of organic matter synthesis minus losses due to respiration and other cellular processes. Respiration is the rate at which organic compounds are utilized by the cells. Because respiration as measured by this method was usually negligible, net production can be considered almost equivalent to gross production.

Over four years (1973-76), the lake average gross productivity was 1245 mg C/m^3-day. This is virtually identical to the 1973-74 average rate of 1253 mg C/m^3-day given by Marshall (1977). The average productivities for 1973-76 by station were 1568 mg C/m^3-day at Station 1, 1325 mg C/m^3-day at Station 4, 1071 mg C/m^3-day at Station 5, and 1015 mg C/m^3-day at Station 6. Thus, productivity was greatest in the north end (1) and lowest in the south end (6), which agrees with the difference in average chlorophyll levels between the two sides of the lake. The Lake Okeechobee average productivity rate of 107 mg C/m^3-hour compares to rates of 0.33 to 1020 mg C/m^3-hour for other Florida lakes (Table 8).

Figures 6 to 10 show seasonal trends at each station. Highest productivity rates occurred in the warmer months, with the peak months being August to October. The second highest period is during May and June. Station 5 usually experienced more pronounced spring and late summer/early fall peaks and mid-summer minimums. This trend coincides with this station's seasonal chlorophyll pattern. Figures 7 and 8 illustrate the higher productivity rates at Stations 1 and 4 compared to Stations 5 and 6.

During 1981-82, productivity was measured only at Stations 2 and 6. Figure 10 shows the distinct difference between these northern and southern

TABLE 7. MEAN ANNUAL GROSS PRIMARY PRODUCTIVITY (mg C/m^3-day) IN LAKE OKEECHOBEE

Station	1973	1974	1975	1976	1973-76 Average	1981-82
1	1,440	1,673	1,826	1,333	1,568	-
2	-	-	-	-	-	2,850
4	1,370	1,419	1,692	820	1,325	-
5	868	1,278	760	1,378	1,071	
6	1,072	1,027	1,154	806	1,015	854
Lake Average	1,188	1,349	1,358	1,084	1,245	1,852

TABLE 8. GROSS PRIMARY PRODUCTIVITY VALUES OF VARIOUS FLORIDA LAKES[1/]

(Lake Okeechobee average gross primary productivity: 107 mg $C/m^3/hr$)

Location	mg $C/m^3/hr$
Lake Apopka	386.0
Lake Dora	1020.0
Lake Harris	37.0
Lake Eustis	274.0
Lake Griffin	183.0
Lake Weir	11.0
Lake Santa Fe	13.5
Lake Newman	53.6
Lake Orange	43.0
Lake Lochloosa	35.6
Lake Altho	10.3
Lake Cooter	87.0
Lake Little Santa Fe	6.6
Lake Little Orange	12.7
Lake Tuscawilla	12.2
Lake Watermelon	5.3
Lake Wauberg	124.3
Lake Bivens Arm	77.5
Lake Burnt	54.4
Lake Elizabeth	0.58
Lake Hawthorn	55.5
Lake Hickory	7.52
Lake Jeggord	4.26
Lake Kanapaha	26.9
Lake Long	1.42
Lake Moss Lee	12.9
Lake Palatka	3.36
Lake Trout	10.5
Lake Clear	69.1
Lake Clearwater	0.33
Lake Meta	3.59
Lake Mize	7.46

[1/] Brezonik, et al 1969; reproduced from Marshall, 1977

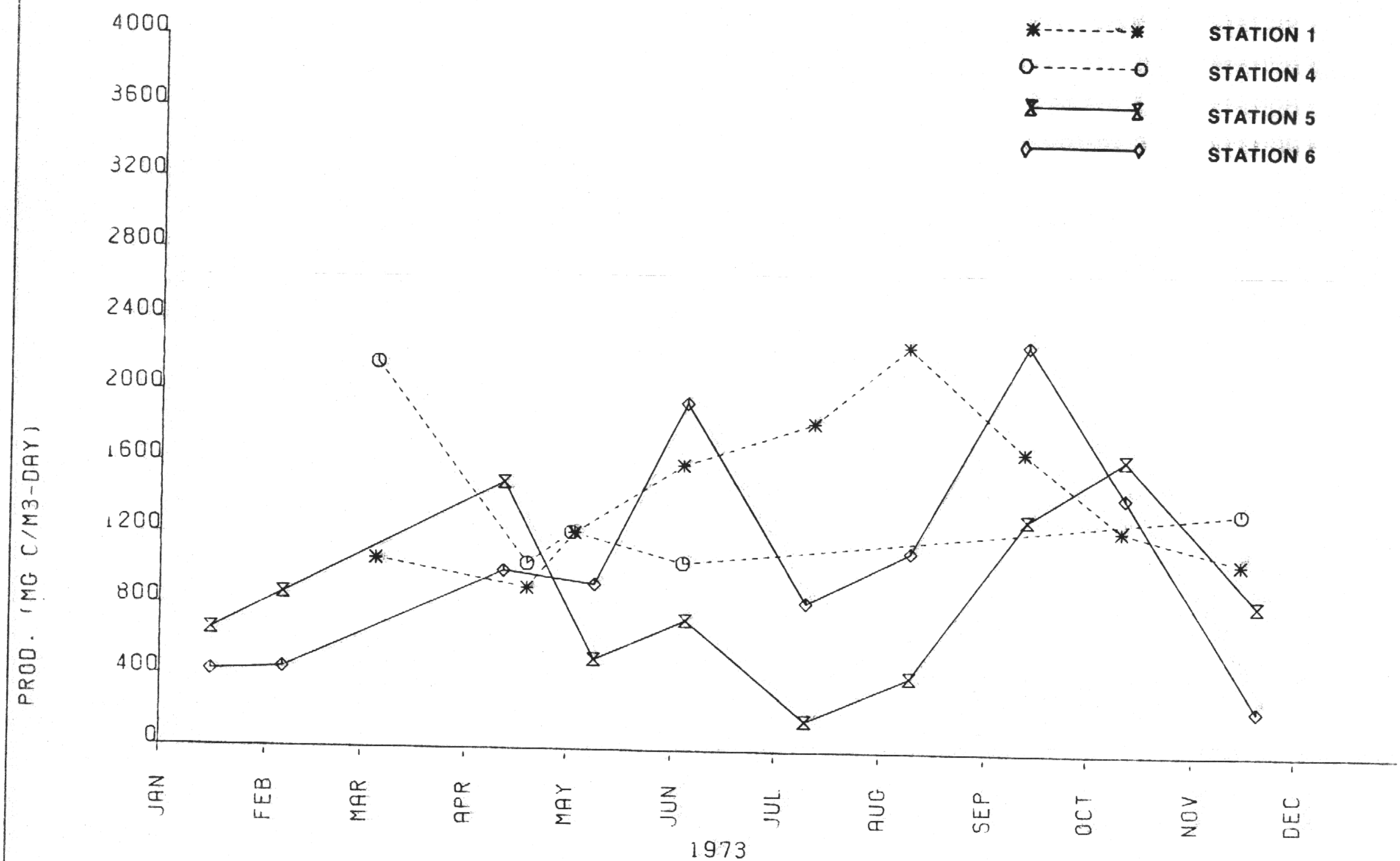


Fig. 6 Gross Primary Productivity 1973

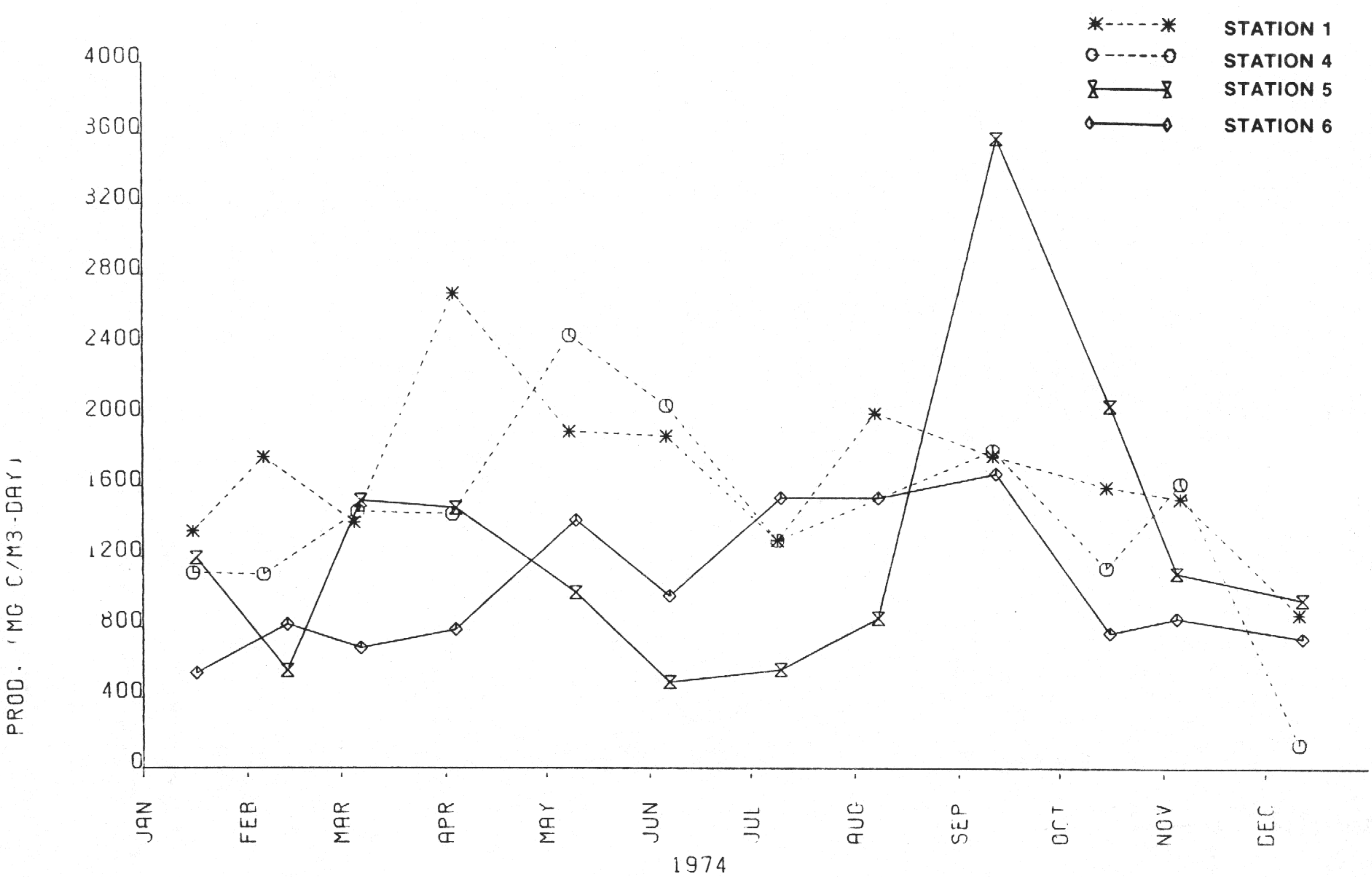


Fig. 7 Gross Primary Productivity 1974

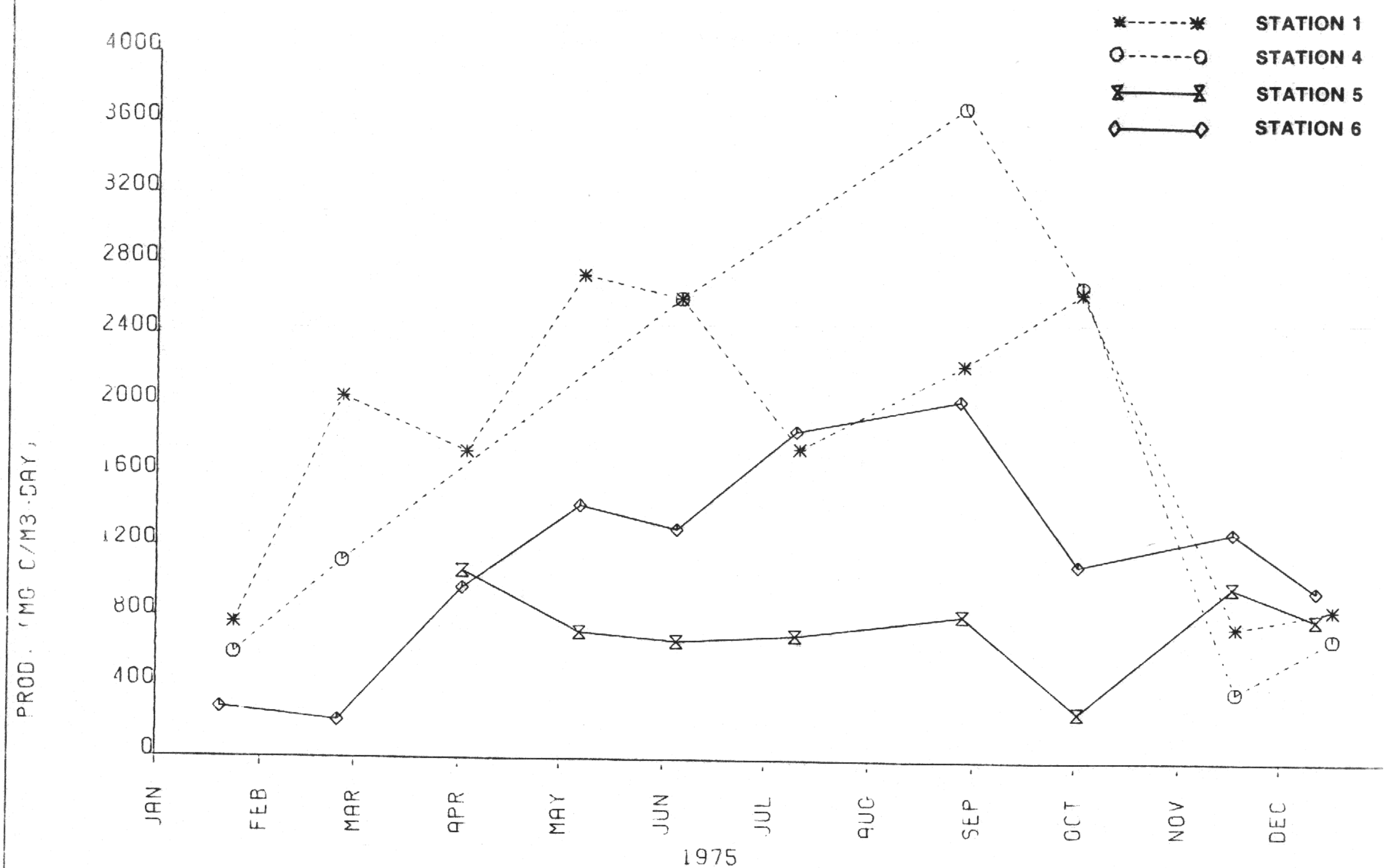


Fig. 8 Gross Primary Productivity 1975

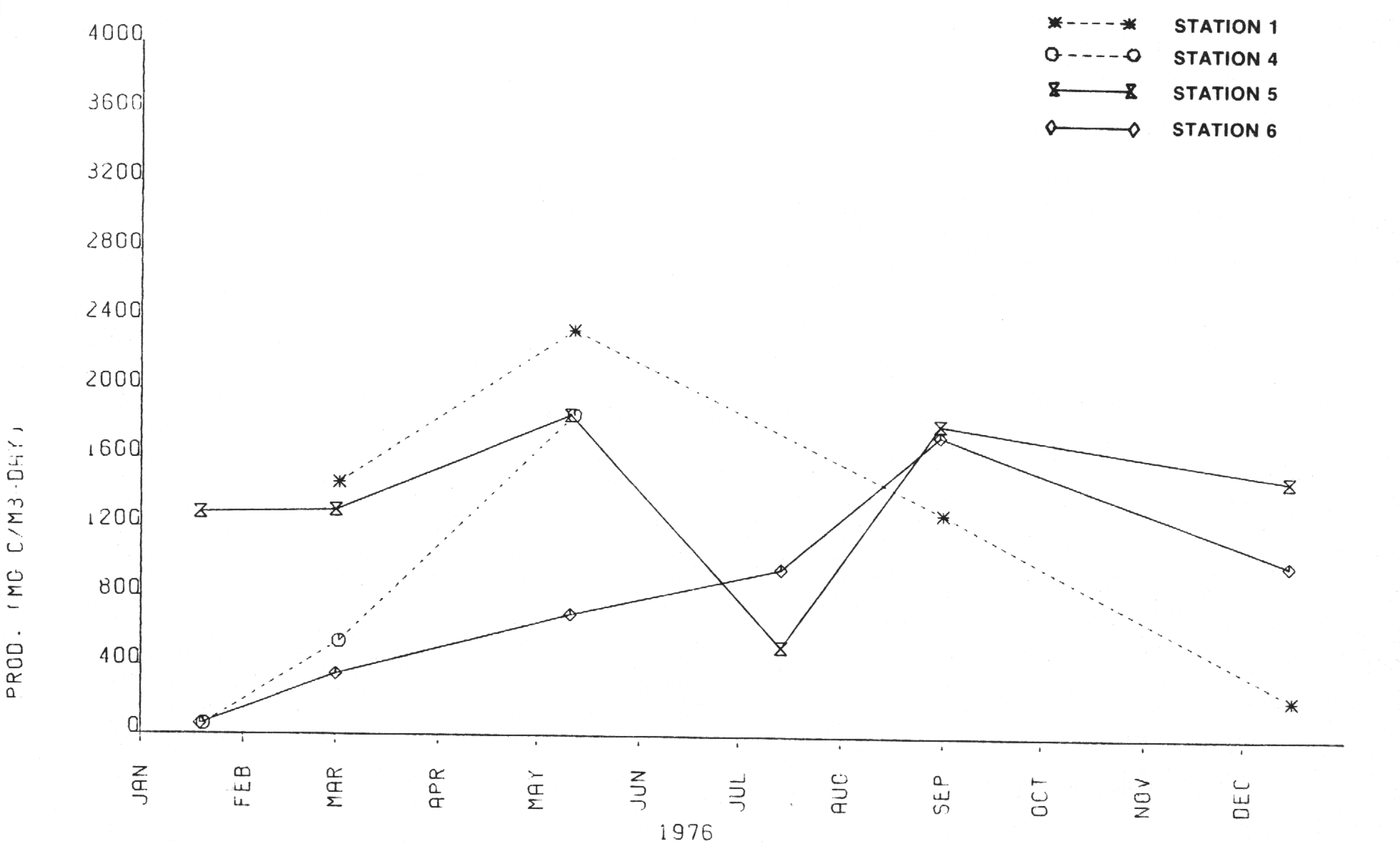


Fig. 9 Gross Primary Productivity 1976

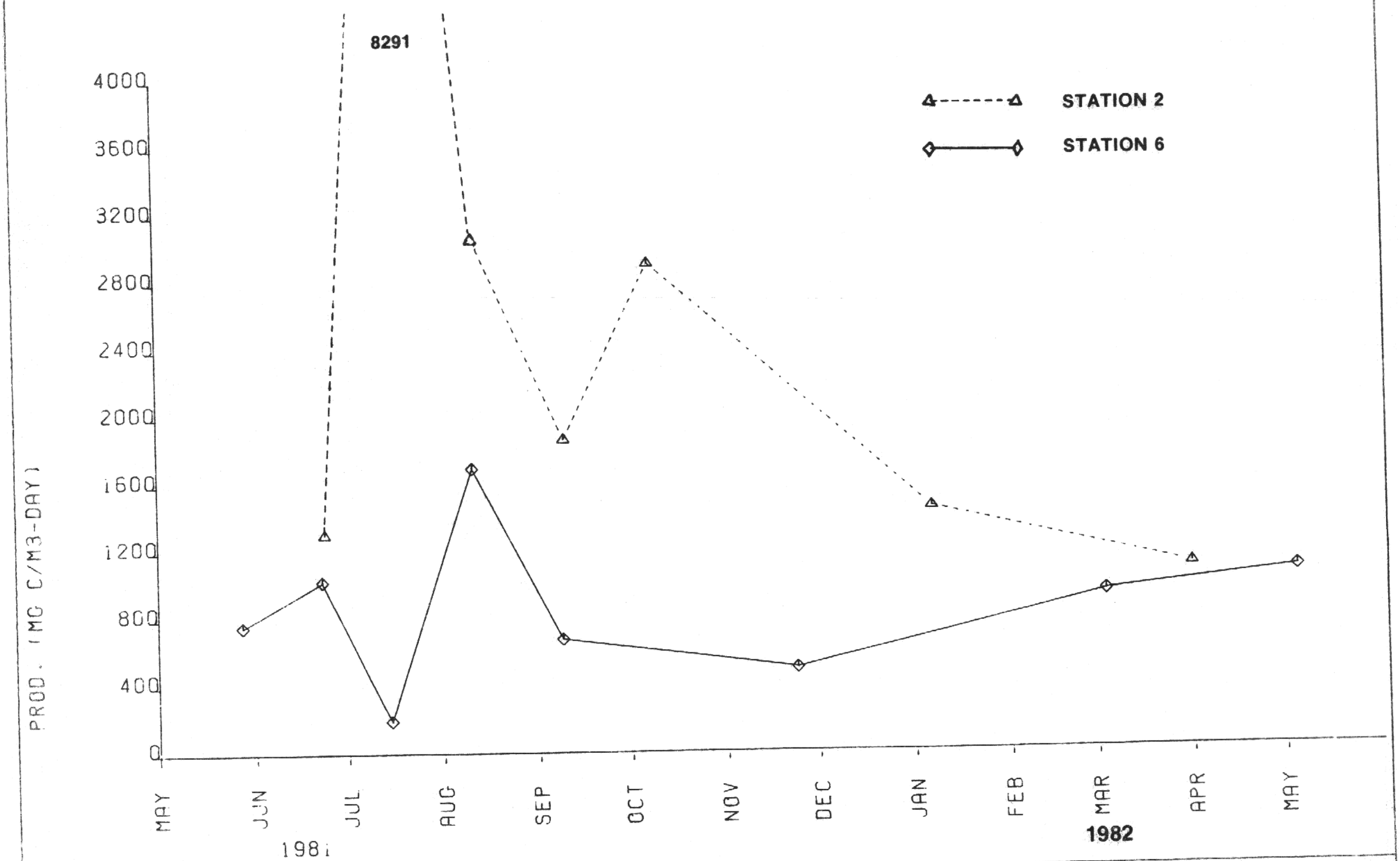


Fig. 10 Gross Primary Productivity 1981-82

stations. In July 1981, a rate of 8291 mg C/m^3-day was measured at Station 2 (during the Rhaphidiopsis bloom mentioned earlier). This is the highest productivity rate observed in Lake Okeechobee and is partly why the average rate at Station 2 is significantly higher than at the other stations.

Phytoplankton Densities and Dominant Species

The three dominant classes of algae found in Lake Okeechobee are the Cyanophyceae (blue-green algae), Bacillariophyceae (diatoms), and Chlorophyceae (green algae). The blue-green algae are the most predominant in terms of number of individuals and form the most significant blooms; however, the diatoms have a greater biovolume because of their larger size. In 1981, only phytoplankton densities (number of cells or colonies per unit volume) were measured. The results (Table 9) show the predominance of the blue-green algae at peak densities. In addition to the classes mentioned above, representatives of the Englenophyceae (euglenoids), Dinophyceae (dinoflagellates), and Cryptophyceae (cryptomonods) were occasionally found in small numbers.

In May 1981, algal density was relatively low at the three stations sampled. The most common blue-green algae were Lyngbya contorta and Agmenellum quadruplicatum, while the most common diatoms were species of Fragilaria and Nitzschia. Chlamydomonas sp., a green algae, was highly visible throughout most of the lake as patches floating on the surface. In May and June, numerous algal mats, probably of Microcoleus sp., were found in the southern portion of the lake. This species grows on the lake bottom and was probably suspended by wave action due to the low lake stage.

A bloom of Rhaphidiopsis curvata was present at Station 2 in July. This blue-green species accounted for 87% of the algal density (118,868 units/ml) at this station. Marshall (1977) also observed blooms of this species in the lake's north end during the summers of 1973-76 and indicated that these blooms originated at Nubbin Slough. However, Nubbin Slough is an unlikely source of

TABLE 9. PHYTOPLANKTON DENSITIES BY CLASS

		Density(units/ml)				
Date	Station	Cyano-phyceae	Bacillario-phyceae	Chloro-phyceae	Others	Total
5-28-81	4	858	590	911	0	2,358
	7	4,502	1,072	214	54	5,842
	8	2,305	3,002	697	214	6,218
7-15-81	2	105,512	13,022	334	0	118,868
	6	870	563	179	101	1,715
8-24-81	2	15,651	7,504	750	107	24,013
	6	2,271	1,102	67	0	3,440
9-10-81	2	34,970	2,305	802	0	38,156
10-8-81	2	2,806	3,340	267	0	6,413
	5	22,378	1,336	1,069	0	24,783
	6	5,344	2,004	264	534	8,146

the 1981 bloom because of the lack of discharge during this period. In contrast, the south end of the lake had low algal concentrations in July.

In August, the difference between the north end and the south end was still apparent. Dominant genera at both Station 2 and Station 6 were *Lyngbya* and *Fragilaria*.

Lyngbya limnetica made up 91% of the sample taken at Station 2 in September. Marshall (1977) noted that this was the most common species observed in 1974, but because of its small size was not important in terms of biovolume. Although not shown in Table 9, a significant bloom of *Anacystis* sp. was present in the lake's southern region in late September. This bloom occurred during a period of high discharge from pump stations S-2 and S-3. It is possible that the introduction of nutrient-laden water from these pump stations contributed to this bloom, although this relationship cannot be proven from the data available.

Algal densities had decreased at Station 2 by October, the most common genus being *Lyngbya*. Phytoplankton numbers at Station 5 were higher, with the dominant organisms being *Anacystis* sp. As shown by the chlorophyll and productivity data, algal populations tend to peak at this station in the spring and late summer/early fall.

Although the data presented here are far from complete, they agree with the trends observed in chlorophyll and primary productivity data. As with these other parameters, algal densities tended to be higher in the north end of the lake than in the south end.

In comparison to the 1974 data collected by Marshall (1977), the 1981 densities appear to be lower (Marshall calculated an average annual density of 144,570 unit/ml), but this may be due in part to a difference in counting techniques. With regard to algal species, many of the dominant organisms observed by Marshall were common in the 1981 samples. *Rhaphidiopsis curvata* has continued to be an important bloom species in the northern portion of the lake. Lake Okeechobee is believed to be the only lake where *R. curvata* has been documented as a dominant species. The *Anacystis* bloom in the south end is a cause for concern since it coincided with intense backpumping into the lake; however, no bloom was detected in 1982.

DISCUSSION

The Everglades Agricultural Area (EAA) and the Taylor Creek/Nubbin Slough watershed (Fig. 1) are the basins that pose the most threat to the eutrophication of Lake Okeechobee. Runoff backpumped from the muck soils of the EAA, through pump stations S-2 and S-3, is high in inorganic nitrogen. Discharge from S-2 and S-3 contributes an average of 26 percent of the annual total nitrogen input to the lake. The Taylor Creek/Nubbin Slough basin contributes the most phosphorus (30%) to the lake (Jones 1983). Phosphorus runoff in this basin is primarily caused by dairy operations. The SFWMD is currently involved in monitoring the effect of Best Management Practices to control nutrient runoff in the Taylor Creek/Nubbin Slough basin, and is diverting EAA runoff away from the lake through the Lake Okeechobee Operating Permit Interim Action Plan. More permanent diversion plans are being pursued. Because of the significant commitment of resources by the SFWMD and other agencies to reduce nutrient inputs from these two basins, it is important to examine possible relationships between these nutrient inputs and lake productivity.

Chlorophyll and productivity data collected from 1973 to 1982 show no general increasing trends. However, 1981 summertime peaks, especially in the north end at Station 2, were higher than observed previously. Considering that inflows, particularly from nutrient-rich tributaries such as Taylor Creek/Nubbin Slough, were very low over the first half of 1981, it is unlikely that an influx of nutrients could have stimulated the bloom at Station 2. On the other hand, backpumping from the EAA could have been responsible for the bloom in the south end later that summer. Alternatively, these blooms could have been a product of the lake's low stage in that year. By July, the lake level had declined more than 6 ft. below regulation stage. The shallower water column could have allowed algae to circulate for a longer time in the euphotic zone, thereby permitting increased production.

The results presented here also show that average algal biomass is greater in the north end than in the south end of the lake. This might indicate that the large phosphorus inputs from Taylor Creek/Nubbin Slough influence algal growth to a greater extent than nutrient inputs from other areas around the lake, including the EAA. Other causes for the greater biomass in the north might be the more consistent inflow of nutrients from the northern tributaries or the greater resuspension of nutrients from the northern mud sediments. This does not mean, however, that inputs from the EAA are less important in the management strategy for Lake Okeechobee. The fact that an algal bloom in the lake's south end followed intensive backpumping of EAA runoff into the South Bay region indicates that this runoff may result in the stimulation of a limnetic bloom under certain conditions. Thus, even though the data do not indicate any long term influence from EAA runoff, there may be temporary impacts. Of course, EAA backpumping also results in major water quality impacts in the Rim Canal and surrounding littoral area (Dickson, et al. 1978; Federico, et al. 1981).

These results suggest that future research should concentrate on two areas. First, the reason for higher chlorophyll and productivity levels in the north end of the lake should be determined. This should include an investigation of the relationship between lake productivity and Taylor Creek/Nubbin Slough inflow. Second, the relationship between algal blooms and water quality should be examined. Work on this has already begun with phytoplankton and water quality samples collected during 1982-83. The objective of this study is to determine if differences in species composition and density can be related to differences in water chemistry in various parts of the lake.

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